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ABSTRACT

The central theme for this document is provided by the report by the National Advisory Committee on Mathematical Education (NACOME), which prepared an overview and analysis of U.S. school-level mathematical education. Topics covered include: (1) a research-supported discussion of several issues facing mathematics educators; (2) suggestions for kindergarten mathematics teacher education; (3) mathematics anxiety, individualization, and learning theory as they relate to mathematics teacher education; (4) specifications for the training of a teacher of general mathematics in junior and senior high schools; (5) a description of a graduate in-service workshop for elementary and secondary teachers; and (6) the secondary mathematics teacher education curriculum for the urban-bound teacher. (MP)

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Mathematics Teacher Education:

Critical Issues and Trends

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Professional Studies

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Douglas B. Aichele, Editor

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Previously published material used in this book may use the pronoun "he" to denote an abstract individual, e.g., "the student." We have not attempted to alter this material, although we currently use "she/he" in such instances.

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CONTENTS

Page

INTRODUCTION
by Douglas B. Aichele 7

Mathematics Teacher Education: An Overview in Perspective
by Douglas B. Aichele 9

Suggestions for Kindergarten Mathematics Teacher Education
by Kathryn Castle 25

The Answer to the Prophets of Doom: Mathematics Teacher Education
by John C. Mihalko 36

Specifications for the Training of a Teacher of General Mathematics in Junior and Senior High Schools: A Recommendation of the Michigan Council of Teachers of Mathematics Directed to the Teacher Training Institutions of Michigan
by Frank Rogers 42

Comments on a K-12 In-Service Course
by Karen Skuldt 50

The Urban-Bound Mathematics Teacher
by Earl E. Hasz 54

Footnotes and References 61

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INTRODUCTION

The current status of mathematics teacher education is largely the effect of the past, especially the recent past since about 1960; and the future will be affected by the concerns of the present—performance-based teacher education (PBTE), competency-based teacher education (CBTE), accountability, basic skills, declining test scores, tests of minimal competencies, etc. Projections for teacher education programs in mathematics must clearly address these effects.

Mathematics teaching today faces the future with little real certainty of its goals and little optimism concerning its potential effectiveness; this bleak outlook has resulted largely from the lack of hard research data as a basis for making decisions. It is not surprising that in May 1974 the Conference Board of the Mathematical Sciences appointed a National Advisory Committee on Mathematical Education (NACOME) to prepare an overview and analysis of U.S. school-level mathematical education including its objectives, current practices, and attainments. The resulting document, the NACOME report, capitalized upon several current nationwide research projects and clearly has significant and far-reaching implications for mathematics teacher education at all levels. It provides the central theme or core for *Mathematics Teacher Education: Critical Issues and Trends.* A priori knowledge of the NACOME report is not a prerequisite for reading this publication, however, since the chapters contributed are directed at selected issues and are not intended to be reactions to the report.

The initial chapter, "Mathematics Teacher Education: An Overview in Perspective," is included to present a research-supported discussion of several timely topics facing mathematics educators. These issues are by no means intended to be exhaustive and, in a sense, they are level-free. With this foundation, a general discussion of mathematics teacher education follows and concludes with the specific pre-service and in-service teacher training recommendations of the NACOME report.

Kathryn Castle prepared the chapter entitled "Suggestions for Kindergarten Mathematics Teacher Education." Reflecting expertise in early childhood education, she has provided an overview of kindergarten teacher education followed by some suggestions for teaching mathematics and logic in the kindergarten. The theme is that teacher preparation in mathematics has been neglected at the kindergarten level. A concentration on the social transmission of mathematics facts has failed and will continue to fail to produce individuals capable of thinking in new ways and inventing new solutions to problems which will confront us in the future. Kindergarten mathematics programs and teacher education programs are required that stress the need to capitalize on the child's intrinsic motivation to learn mathematics concepts and to facilitate the development of the capacity for logical thought.

John Mihalko has documented his many years of classroom experience in the chapter, "The Answer to the Prophets of Doom: Mathematics Teacher

Education." He presents a brief overview of the era of "new math" and then discusses math anxiety, individualization, and learning theory as they relate to mathematics teacher education.

Frank Rogers, a consultant in mathematics in the Lansing Public Schools, prepared the chapter entitled "Specifications for the Training of a Teacher of General Mathematics in Junior and Senior High Schools: A Recommendation of the Michigan Council of Teachers of Mathematics Directed to the Teacher Training Institutions of Michigan." Teacher training in mathematics requires, and will continue to require, many more hours of clinical experiences, i.e., many more hours of on-the-job exposure to real students at the grade levels that pre-service students are preparing themselves to teach. This chapter includes specific suggestions as to how these clinical experiences can be structured and where the classroom hours in pure mathematics classes can be rearranged to make time for them.

Karen Skuldt's chapter, "Comments on a K-12 In-Service Course," is a description of a graduate in-service workshop offered at the State University College of Arts and Science in Geneseo, New York, in which elementary and secondary teachers explore concerns and issues they share regarding the teaching of mathematics.

Earl Hasz developed the chapter, "The Urban-Bound Mathematics Teacher." His focus is on the secondary mathematics teacher education curriculum at Metropolitan State College in Denver and its raison d'être.

The experiences and current activities of the panel of contributors are clearly different and diverse, thereby providing the reader with a variety of positions to consider. We hope that the overviews, position papers, and program descriptions presented in *Mathematics Teacher Education: Critical Issues and Trends* contribute to a more objective base for making decisions in mathematics teacher education.

DOUGLAS B. AICHELE

MATHEMATICS TEACHER EDUCATION: AN OVERVIEW IN PERSPECTIVE

Douglas B. Aichele, Professor of Curriculum and Instruction and Mathematics, and Director of Student Teaching, Oklahoma State University, Stillwater, Oklahoma

If we were to try to give a scouting report on the current status of mathematics teacher education, I suppose we would have to conclude that it is largely the effect of the past, especially the recent past since about 1960; and the future will be affected by the concerns of the present—performance-based teacher education (PBTE), competency-based teacher education (CBTE), accountability, basic skills, declining test scores, tests of minimal competencies, etc. Projections for teacher education programs in mathematics clearly must address these effects.

One of the problems in confronting any of these areas, however, concerns a real lack of hard research data. For example, let's consider the mathematics curriculum. We cannot seem to gain consensus on the geometry curriculum, or, more generally, on exactly what mathematics should be taught in American schools. If, as mathematics educators, we cannot seem to agree on the content to be taught, how then can programs be designed and supported to prepare mathematics teachers? Quite clearly, this question is not fair as it does not relate the whole story. It does depict, however, concerns that parents, legislators, and the public entertain in general as they extrapolate from their own mathematical experiences to those of their offspring, patrons, and friends.

It is impossible to consider the issues of mathematics teacher education in isolation. We must realize that the discipline of mathematics, as perceived by the public and mathematics educators alike, has undergone some very real criticism recently; and this criticism alone has had extreme negative implications. During the era of "new math," mathematics educators assumed a pro-active posture. There was a tremendous spirit that reflected curriculum development supported largely by state and federal agencies; there was little research conducted to assess and justify these curriculum proposals and their influence on the mathematical development of American youth as a whole. This flurry of activity was overactive in some respects and perhaps reflected an overemphasis on such dimensions as symbolism, vocabulary, and abstraction. It is also true that some of the less desirable by-products of the "new math" era have been presented to the public in a negative manner and have been erroneously generalized to all of mathematics. Mathematics historically has been thought difficult, uninteresting, and perhaps sterile by many people. So what was new in the 1960s? What was new was that parents and the public in general were unable to understand, much less help their offspring with, the mathematics being taught in schools; furthermore, in addition to anxious parents, there were anxious teachers! It is no wonder that the result was some pretty anxious students. Are today's citizens supporting the anxieties they experienced as students during the "new math" era?

In May 1974 the Conference Board of the Mathematical Sciences appointed a National Advisory Committee on Mathematical Education (NACOME) and directed the committee to prepare an overview and analysis of U.S. school-level mathematical education including objectives, current practices, and attainments. The composition of the committee was extremely diverse with present activities of the membership spanning classroom teaching of mathematics from elementary grades through graduate school, mathematical research, pre- and in-service teacher education, curriculum development and implementation projects, supervision of curriculum and instruction, and evaluation of programs in school mathematics and teacher education. The activities of committee members also reflected experience in rural, suburban, and urban schools from across the United States and several foreign countries. The final report of the committee, the NACOME report (9), was released in 1975. One of its recommendations speaks explicitly to the issue of the "new math" era and sets the stage for the future.

> *In the creation, introduction, and support of mathematics programs, neither teachers, educational administrators, parents, nor the general public should allow themselves to be manipulated into false choices between*
>
> > *the old and new in mathematics*
> > *skills and concepts*
> > *the concrete and the abstract*
> > *intuition and formalism*
> > *structure and problem-solving*
> > *induction and deduction*
>
> *The core of every mathematics program should contain a judicious combination of both elements of each pair with the balance, proportion, and emphasis between the two being determined by the goals of the program and by the nature, capabilities and circumstances of the students and teachers in the program.*
>
> *Furthermore, little is communicated by polarization of positions about terms and slogans that have long since lost agreed-upon meanings. Therefore, we recommend the term "new math" be limited in its use to describe the multitude of mathematics education concerns and developments of the period 1955-1975 and that reference to current school mathematics, its status, its trends, and its problems be made only in such common-noun terms as the "present mathematics program," "current school mathematics," "contemporary mathematics teaching," etc. (9:136-37)*

Discussions related to characterizing "new math" no longer exist as they did at one time. Professional meetings no longer support sessions related to the topic; the times are filled with discussions of other scapegoats such as basic skills, tests of minimal competence, and the metric system. Hopefully, we have learned something from the "new math" era, and consequently we will be better able to enjoy

increased public credibility largely as a result of communicating our positions on future issues accurately and objectively to the public at large. If not, the future will probably turn into a sequence of disasters which would make *Alice in Wonderland* appear a reality.

Release of the NACOME report in 1975 was timed to take advantage of the results of the first assessment in mathematics (1972-73) of the National Assessment of Educational Progress (NAEP), a survey of course offerings and enrollments in public secondary schools during 1972-73 of the National Center for Educational Statistics (NCES), a published survey in 1975 of the American Institutes for Research (AIR) entitled *Computing Activities in Secondary Education*, and a survey supported by the Association of State Supervisors of Mathematics (ASSM). These documents provided a sound basis from which a report could evolve and perhaps represent a benchmark for the future.

Basic Skills and Tests of Minimal Competence

An issue spoken to in the NACOME report which is much discussed today concerns the "basic skills." The report recommends

> *that every child is entitled to the mathematical competencies necessary for daily living in today's civilization, but the concept of "basic skills" essential to the consumer and the citizen [should] be defined to include more than computational skill–also abilities to deal intelligently with statistical information, to reason logically and think critically. (9:137)*

Very few would disagree with the spirit of this statement; the problem, however, is that many individuals perceive the general "basic skills" issue as the vehicle for getting to the larger issue of "tests of minimal competency." One might legitimately ask, "Are there basic skills of mathematics?" If so, what are they? Initially, the task of enumerating these "basic skills," assuming they exist, does not appear to be such a difficult undertaking. However, as the results of the Euclid Conference on Basic Mathematical Skills and Learning (1) clearly showed, it is difficult (perhaps even futile) to gain consensus on just what constitutes basic skills in mathematics.

Now, taking the issue one step further, school districts throughout the country are currently involved in assessing basic mathematical skills and then using these assessments to develop tests of minimal competence which ultimately will be used to identify students who have not developed their basic mathematical skills–whatever those skills are. How did we ever get into such a precarious situation? It probably happened because we allowed some form of very narrow definition of basic skills to equate competence in mathematics with ability to perform mathematical computations à la the "four basic operations." And this resulted from the media's misrepresentation of such forces as declining standardized test scores and college entrance examination scores, reactions to the results of the National Assessment of Educational Progress, rising costs of education and the accountability movement, and trends in mathematics education emphasizing instructional methods and alternatives rather than curriculum content.

The lack of consensus resulting from the Euclid conference by no means went unnoticed. Even though any attempt to gain universal agreement on a unique set of basic mathematical skills is doomed, the attempt to identify such skills can be helpful to teachers, parents, and the public. The process of interacting ideas and attempting to describe "basic skills" in light of past attempts and then assimilating the resulting ideas is a worthwhile undertaking. It illustrates the extreme difficulty of the problem and reveals that what is "basic" today may not be "basic" tomorrow. One organized response to the results of the Euclid conference came from the National Council of Supervisors of Mathematics (13). Their position paper did not take a stand on the issue concerning testing minimal competencies as a determinant for high school graduation. Instead, they identified ten components of basic skills that could serve as guidelines for state and local school systems considering the establishment of minimum essential graduation requirements. These are:

1. *Problem Solving*

   Learning to solve problems is the principal reason for studying mathematics. Problem solving is the process of applying previously acquired knowledge to new and unfamiliar situations. Solving word problems in tests is one form of problem solving, but students also should be faced with non-textbook problems. Problem-solving strategies involve posing questions, analyzing situations, translating results, illustrating results, drawing diagrams, and using trial and error. In solving problems, students need to be able to apply the rules of logic necessary to arrive at valid conclusions. They must be able to determine which facts are relevant. They should be unfearful of arriving at tentative conclusions and they must be willing to subject these conclusions to scrutiny.

2. *Applying mathematics to everyday situations*

   The use of mathematics is interrelated with all computation activities. Students should be encouraged to take everyday situations, translate them into mathematical expressions, solve the mathematics, and interpret the results in light of the initial situation.

3. *Alertness to the reasonableness of results*

   Due to arithmetic errors or other mistakes, results of mathematical work are sometimes wrong. Students should learn to inspect all results and to check for reasonableness in terms of the original problem. With the increase in the use of calculating devices in society, this skill is essential.

4. *Estimation and approximation*

   Students should be able to carry out rapid approximate calculations by first rounding off numbers. They should acquire some simple

techniques for estimating quantity, length, distance, weight, etc. It is also necessary to decide when a particular result is precise enough for the purpose at hand.

5. *Appropriate computational skills*

   Students should gain facility with addition, subtraction, multiplication, and division with whole numbers and decimals. Today it must be recognized that long, complicated computations will usually be done with a calculator. Knowledge of single-digit number facts is essential and mental arithmetic is a valuable skill. Moreover, there are everyday situations which demand recognition of, and simple computations with common fractions.

   Because consumers continually deal with many situations that involve percentage, the ability to recognize and use percents should be developed and maintained.

6. *Geometry*

   Students should learn the geometric concepts [they] will need to function effectively in the 3-dimensional world. They should have knowledge of concepts such as point, line, plane, parallel, and perpendicular. They should know basic properties of simple geometric figures, particularly those properties which relate to measurement and problem-solving skills. They also must be able to recognize similarities and differences among objects.

7. *Measurement*

   As a minimum skill, students should be able to measure distance, weight, time, capacity, and temperature. Measurement of angles and calculations of simple areas and volumes are also essential. Students should be able to perform measurement in both metric and customary systems using the appropriate tools.

8. *Reading, interpreting, and constructing tables, charts, and graphs*

   Students should know how to read and draw conclusions from simple tables, maps, charts, and graphs. They should be able to condense numerical information into more manageable or meaningful terms by setting up simple tables, charts, and graphs.

9. *Using mathematics to predict*

   Students should learn how elementary notions of probability are used to determine the likelihood of future events. They should learn to identify situations where immediate past experience does not affect the likelihood of future events. They should become

familiar with how mathematics is used to help make predictions such as election forecasts.

10. Computer literacy

It is important for all citizens to understand what computers can and cannot do. Students should be aware of the many uses of computers in society, such as their use in teaching/learning, financial transactions, and information storage and retrieval. The "mystique" surrounding computers is disturbing and can put persons with no understanding of computers at a disadvantage. The increasing use of computers by government, industry, and business demands an awareness of computer uses and limitations. (13:20)

Once again, it is important to remember that the skills held as basic by our society today are likely to change in the future. The dual systems of measurement with us today (English and metric) will probably not be with us in ten years; the role of hand-held calculators and computing devices will greatly influence the manner in which problems will be solved and the very nature and type of problems considered. We cannot afford to fall into the trap of believing that basic skills are static and will not change with time and technological advances.

Some rather monumental curriculum recommendations were also presented in the NACOME report. These recommendations appear to be reasonable and rather essential features of a contemporary mathematics curriculum.

1. *That logical structure be maintained as a framework for the study of mathematics.*

2. *That concrete experiences be an integral part of the acquisition of abstract ideas.*

3. *That the opportunity be provided for students to apply mathematics in as wide a realm as possible—in the social and natural sciences, in consumer and career related areas, as well as in any real life problems that can be subjected to mathematical analysis.*

4. *That familiarity with symbols, their uses, their formalities, their limitations be developed and fostered in an appropriately proportioned manner.*

5. *That beginning no later than the end of the eighth grade, a calculator should be available for each mathematics student during each mathematics class. Each student should be permitted to use the calculator during all of his or her mathematical work including tests.*

6. *That the recommendations of the Conference Board of the Mathematical Sciences 1972 committee regarding computers in secondary school curricula be implemented.*

NACCME especially underlines recommendations:

–that all *students, not only able students, be afforded the opportunity to participate in computer science courses,*

–that school use of computers be exploited beyond the role of computer assisted instruction or computer management systems,

–that "computer literacy" courses involve student "hands-on" experiences using computers.

7. *That all school systems give serious attention to implementation of the metric system in measurement instruction and that they re-examine the current instruction sequences in fractions and decimals to fit the new priorities.*

8. *That instructional units dealing with statistical ideas be fitted throughout the elementary and secondary school curriculum. (9:138-39)*

Several of these recommendations stress issues that are not new to mathematics educators, e.g., logical structure of mathematics, using concrete experiences to acquire abstract ideas, symbolism in moderation, and application of mathematics presented in a variety of settings. Positions on calculators, computer literacy, statistics, and the metric system are necessary as these issues are already very real. These recommendations provide us with a basis from which we can exercise leadership in the direction deemed most appropriate.

National Assessment of Educational Progress

One of the forces mentioned earlier that has tended to have a negative influence on recent developments of school mathematics is media publicity given to selected results from the 1975 reports of the National Assessment of Educational Progress (NAEP) (10, 11, 12). As a result of testing done during 1972-73, these reports describe achievement of 9, 13, 17 year olds, and young adults aged 26-35 in fifteen content strands at six levels of behavioral complexity. The content of the assessment was evaluated as appropriate for American schools by scholars, lay persons and educators. Clearly, this first assessment does not provide all the answers. It does, however, identify topics in the curriculum that should be given increased emphasis. Furthermore, the particular results on the computation part of the assessment do not support the allegations that basic skills seriously deteriorated during the "new math" era (9:118). On the other hand, the reports suggest that the curriculum should reflect more attention to the basic concepts related to measurement and problem analysis (9:118).

It would be impossible to review all of the findings of this first assessment. Unfortunately, the results of such studies too often go unnoticed. I strongly suggest that as mathematics departments within school districts contemplate curriculum revision they utilize these NAEP results. This would help to eliminate some of the negative comments frequently espoused by secondary mathematics teachers related to the poor job their counterparts are doing at the middle school or junior high school level; it would also provide some hard research data in support of curriculum revision. Knowledge of these results is not restricted to public school teachers. Quite the contrary—these results provide the most current analysis and description of the mathematical abilities of a cross-section of Americans. Mathematics educators at all levels should be familiar with them and be eagerly awaiting the reports of the second assessment.

Scholastic Aptitude Test Score Decline

Another negative force mentioned earlier was media publicity given to declining standardized test scores and college entrance examination scores during the past two decades. The causes for the decline in the performance of entering college students on the Scholastic Aptitude Test (SAT) were studied by a panel appointed in 1975 by the College Entrance Examination Board (CEEB). This panel, under the chairmanship of Willard Wirtz, made its report available in August 1977 (2). Briefly, the SAT has been used for over fifty years to help determine high school students' preparedness for college. The test includes two parts, Verbal and Mathematical, each computed and reported separately on a scale of 200-800. The mathematical portion measures students' problem-solving ability in three areas—arithmetic reasoning, elementary algebra, and geometry (2:3). In 1952 the SAT-Mathematical average for all test-takers was 494 (2:6). These scores remained relatively stable for the period 1952-63 although a slight increase was reported in 1963 when the average was up 8 points to 502 (2:6). The decline began in 1964 on both the SAT-Mathematical and SAT-Verbal. It remained relatively gradual until about 1970 and became sharper after that, especially on the SAT-Verbal. The past two years have suggested a possible leveling out; the SAT-Mathematical in 1977 was 471 for all test-takers (2:6).

The panel concentrated on the period 1963-77, observing a decline of 31 points on the mathematical portion and 49 points on the verbal portion. In terms of standard deviations, the decline in scores means that only about a third of the 1977 test-takers did as well as half of those who took the SAT in 1963 (2:5). It is very difficult to determine precisely *how much* worse students are doing now than their counterparts did earlier. This decline is nothing to be taken lightly, however, especially when it followed a period with relatively stable scores—even slightly increasing scores.

The panel diagnosed the causal factors of the score decline as falling into two categories or stages. These categories are actually so different that it may be best to think in terms of two score declines. One decline is directly related to changes in the SAT-taking population—"compositional" changes. The data gathered by the panel indicated that starting in about the mid-1960s, cumulatively larger

percentages of students with comparatively lower high school grade averages were going on to college. The ACE Freshman National Norm study shows this directly, as do the ACT Student Profile data for those students taking that college entrance examination (2:14). Most–probably two-thirds to three-fourths–of the SAT score decline from 1963-70 was related to the "compositional" changes in the group being tested (2:45); these score averages measure a different and broader cross section of students than they did in the past. This period was clearly one of expansion in the number and proportion of students completing high school and reflected the national spirit of extended educational opportunity. The panel does not attribute the score decline during this period solely to the fact that an increased percentage of lower-scoring groups started taking the test, however. "What the decline reflects is the incompleteness so far of the national undertaking to afford meaningful equality of educational opportunity." (2:45)

It is much more difficult to characterize the causes for the score decline after 1970; however, the composition of the SAT-taking population has become more stabilized (2:46). There is evidence that prior to 1970 there were emerging signs of "pervasive" influences which went beyond the "compositional" changes. The panel attributed about a quarter of the decline since 1970 to those "compositional" factors related to changing membership in the population being tested. This suggests that about half of the decline may be attributed to a broad collection of factors identified as "pervasive." Briefly stated, these are:

1. *There has been a significant dispersal of learning activities and emphasis in the schools, reflected particularly in the adding of many elective courses and a reduction of the number of courses that all students alike are required to take. . . .*

2. *There is clearly observable evidence of diminished seriousness of purpose and attention to mastery of skills and knowledge in the learning process as it proceeds in the schools, the home, and the society generally. This takes a variety of apparently disparate but actually interrelated forms: automatic grade-to-grade promotions, grade inflation, the tolerance of increased absenteeism, the lowering of the demand levels of textbooks and other teaching and learning materials, the reduction of homework, the lowering of college entrance standards, and the inclusion of "remedial" courses in post-secondary education.*

   Each of these issues presents its own quandary. We are not suggesting simplistic *"solutions" through which all students are treated alike by being held in a grade until they reach a common standard . . . .The only right answer is to vary the instructional process still more to take account of increased individual differences, but without lowering standards. . . .*

3. *Particularly because of the impact of television, but as a consequence of other developments as well, a good deal more of most*

children's learning now develops through viewing and listening than through traditional modes. Little is known yet about the effects of this change, including its relationship to performance levels on standardized examinations.

We surmise that the extensive time consumed by television detracts from homework, competes with schooling more generally, and has contributed to the decline in SAT score averages. Yet we are convinced that television and related forms of communication give the future of learning its greatest promise. . . .

4. *There have unquestionably been changes, during the period relating to score decline, in the role of the family in the educational process. Social sensitivity has precluded thorough inquiry into this area, so that only the readily observable structural changes can be noted: the rapidly increasing number and percentage of children, for example, in less than complete families. While evidence is not available to determine the effect of these changes on students' college entrance examination scores, our conjecture is that it is negative.*

5. *The concentration of score declines in the three-year period between 1972 and 1975 leads the panel to suspect strongly that one important element here was the disruption in the life of the country during the time when those groups of test takers were getting ready for their college entrance examinations.*

6. *For whatever combination of reasons, there has been an apparent marked diminution of young people's learning motivation, at least as it appears to be related, directly or indirectly, to their performance on college entrance examinations. Although this may be largely only another dimension of the preceding points, it is perhaps most significant of all that during the past 10 years the curve of the SAT scores has followed very closely the curve of the entire nation's spirits and self-esteem and sense of purpose. (2:46-48)*

With all due respect to the panel, they attempted only to analyze the declining SAT scores; they were not charged with making recommendations designed to reverse the decline. This is the responsibility of others. It is being fulfilled in part by the recommendations formulated by a joint committee of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM). This committee's recommendations are:

1. *Proficiency in mathematics cannot be acquired without individual practice. We, therefore, endorse the common practice of making regular assignments to be completed outside of class. We recommend that parents encourage their children to set aside sufficient time each day to complete these assignments and that parents actively support the request of teachers that homework be turned*

in. Students should be encouraged to develop good study habits in mathematics courses at all levels and should develop the ability to read mathematics.

2. *Homework and drill are very important pedagogical tools used to help the student gain understanding as well as proficiency in the skills of arithmetic and algebra; but students should not be burdened with excessive or meaningless drill. We, therefore, recommend that teachers and authors of textbooks step up their search for interesting problems that provide opportunity to apply these skills. We realize that this is a difficult task, but we believe that providing problems that reinforce manipulative skills as a by-product should have high priority, especially those that show that mathematics helps solve problems in the real world.*

3. *We are aware that teachers must struggle to maintain standards of performance in courses at all levels from kindergarten through college and that serious grade inflation has been observed. An apparent growing trend to reward effort or attendance rather than achievement has been making it increasingly difficult for mathematics teachers to maintain standards. We recommend that mathematics departments review evaluation procedures to insure that grades reflect student achievement. Further, we urge administrators to support teachers in this endeavor.*

4. *In light of 3 above, we also recognize that advancement of students without appropriate achievement has a detrimental effect on the individual student and on the entire class. We, therefore, recommend that school districts make special provisions to assist students when deficiencies are first noted.*

5. *We recommend that cumulative evaluations be given throughout each course, as well as at its completion, to all students. We believe that the absence of cumulative evaluation promotes short-term learning. We strongly oppose the practice of exempting students from evaluations.*

6. *We recommend that computers and hand calculators be used in imaginative ways to reinforce learning and to motivate the student as proficiency in mathematics is gained. Calculators should be used to supplement rather than to supplant the study of necessary computational skills.*

7. *We recommend that colleges and universities administer placement examinations in mathematics prior to final registration to aid students in selecting appropriate college courses.*

8. *We encourage the continuation or initiation of joint meetings of college and secondary school mathematics instructors and counselors*

in order to improve communication concerning mathematics prerequisites for careers, preparation of students for collegiate mathematics courses, joint curriculum coordination, remedial programs in schools and colleges, an exchange of successful instructional strategies, planning of in-service programs, and other related topics.

9. *Schools should frequently review their mathematics curricula to see that they meet the needs of their students in preparing them for college mathematics. School districts that have not conducted a curriculum analysis recently should do so now, primarily to identify topics in the curriculum which could be either omitted or de-emphasized, if necessary, in order to provide sufficient time for the topics included in the above statement. We suggest that, for example, the following could be de-emphasized or omitted if now in the curriculum:*

   (A) logarithmic calculations that can better be handled by calculators or computers,

   (B) extensive solving of triangles in trigonometry,

   (C) proofs of superfluous or trivial theorems in geometry.

10. *We recommend that algebraic concepts and skills be incorporated wherever possible into geometry and other courses beyond algebra to help students retain these concepts and skills. (8)*

Mathematics Teacher Education

Now that we have presented a little more objective perspective in connection with basic skills, minimal competence, and declining achievement in mathematics, we are in a better position to consider mathematics teacher education. Once again, we must mention at the outset that a lack of hard data related to programs, practices, requirements, and characteristics of the products tends to cloud the issues.

Let's start by taking a look at the situation prevailing at the elementary level. The NCTM commissioned a study (14) concerning characteristics and teaching practices of elementary school teachers. Information was obtained through questionnaires from randomly selected second and fifth grade teachers. The overwhelming conclusion of the study was that mathematics teachers and mathematics classrooms have changed far less in the past 15 years than was speculated. The oversimplification noted is probably not too misleading:

1. *The "median" teacher is a woman under 40 years of age who has been teaching 10 years or less. She has had two semesters of high school algebra, two of high school geometry, and two mathematics courses plus one course in mathematics education in college. She belongs to no association of mathematics teachers and has observed*

someone else teaching a mathematics class two or three times at most (exclusive of master teacher, student teacher, and supervising teacher), but she believes that watching someone else teach mathematics to children could improve her teaching. In contrast to the teachers in the Berkeley study, she is likely to find mathematics easy and interesting to teach.

2. *The "median" classroom is self-contained. The mathematics period is about 43 minutes long, and about half of this time is devoted to written work. A single text is used in whole-class instruction. The text is followed fairly closely or very closely, but students are likely to read at most one or two pages out of every five pages of textual material other than problems. It seems likely that the text, at least as far as the students are concerned, is primarily a source of problem lists. Teachers are essentially teaching the same way that they were taught in school. Almost none of the concepts, methods, or big ideas of modern mathematics programs have appeared in this median classroom. (14:330)*

It appears that the typical elementary pre-service program today consists of one or two courses in mathematics covering number systems and perhaps some informal geometry and a method of teaching mathematics course. To some extent the 1961 and 1966 recommendations of the MAA's Committee on the Undergraduate Program in Mathematics (CUPM) (4, 5) were influential even though their emphasis was restricted to the mathematical content component. The 1971 CUPM recommendations (6) were clearly a revision of the earlier ones but still were directed at the content component of the teacher's preparation.

At the senior high school level, mathematics teacher preparation has changed very little since the 1960s. There are a few exceptions, however; more students are likely to have been exposed to computers, probability and statistics, combinatories and applications, This situation is probably more related to technological advances rather than premeditated curriculum revisions even though these areas were mentioned in the 1971 CUPM recommendations. Of perennial concern to the profession is the geometry preparation of high school mathematics teachers. A lack of consensus on the part of the mathematics education profession as to the kind of geometry courses necessary for teachers as well as a waning commitment from mathematics departments account for much of this problem.

A recent study by Johnson and Byars (7) clearly indicates that much progress has been made by institutions of higher learning in meeting the CUPM recommendations; and supports a need for more coursework in probability and statistics, computer science, geometry, and applications. The study also cites a need for experiences specifically designed for the preparation of junior high school mathematics teachers.

In 1973 the NCTM sponsored the Commission on Education of Teachers of Mathematics (CETM) and subsequently published *Guidelines for the Preparation*

of Teachers of Mathematics (3). These guidelines are stated in terms of specific competencies and mathematical content, contributions of humanistic and behavioral studies, teaching and learning theory with laboratory and clinical experiences, practicum and precertification teaching. They were intended to cover the full spectrum of pre-service elementary and secondary teacher preparation. A comparison of the 1971 CUPM recommendations and the 1973 NCTM guidelines is difficult because of the difference in formats. The conclusion of the NACOME report is that there appear to be no conflicts in the extent or emphasis on particular topics, however; their judgment is that the recommendations and guidelines are compatible. Taken together, they appear to be the pertinent guidelines for use in evaluating mathematical education components of teacher education programs. Hopefully, visitations from the National Council for Accreditation of Teacher Education (NCATE) reflect consistent investigation of these prescribed standards.

It seems clear that if we are ever to make any headway, then, that mathematics educators, mathematicians, professional organizations, and accrediting agencies of certification must all cooperate to produce a "complete" mathematics teacher. The NACOME report recommendation concerned with pre- and in-service teacher training presents an acceptable position and a basis for the remaining chapters of this book:

1. *That professional organizations continue to update and publish the profession's view of the educational needs of mathematics teachers and that professional organizations take an active and aggressive role in apprising decision-makers in teacher education, certification, and accreditation of these views.*

2. *That a joint commission of NCTM and MAA be established to present a united position on requirements for the education of precollege mathematics teachers.*

3. *That the professional organizations in mathematics education take initiatives to insure that mathematics educators have a role in decisions relating to the preparation of specialist teachers in special education, early childhood education, bilingual education, career education and other areas in which mathematics is part of the curriculum.*

4. *That mathematics specialists with broad- and long-range perspective concerning the nature of mathematics and its role in society (mathematicians and mathematics educators) maintain a prominent role in decisions concerning the mathematical competencies of teachers, both in design of teacher education programs and in the certification of teachers.*

5. *That neither teacher education nor certification procedures be based solely on competency- or performance-based criteria without a sound empirical rationale.*

6. *That the background of instructors in both pre-service and in-service courses for teachers include not only the relevant mathematical competence but both current experience and interest in the mathematical curriculum of the level those teachers will teach.*

7. *That, since the successful implementation of any thrust in school mathematics depends on the realistic acceptance of that thrust by teachers, programs seeking national acceptance must identify the factors promoting such acceptance and integrate these into in-service workshops. Among the factors considered should be:*

   –the conditions under which the teacher is attending the institute,

   –the teacher's opportunity to make input into the program,

   –the teacher's opportunity to adapt methods or materials to his or her own style of classroom instruction,

   –the opportunity to air misgivings and apprehensions and to brainstorm both future difficulties of implementation and alternatives for avoiding or handling them.

8. *That school districts, teacher organizations, and sponsoring agencies of teacher education programs should work together to identify the conditions that will promote teacher participation in in-service programs. Possible factors might be released time, educational leave time, university credit, stipends, credits toward other negotiated benefits, and incentives teaching materials.*

9. *That teacher education place emphasis in the following areas:*

   a) the development of process abilities, that is, abilities in logical reasoning and problem solving, and methods of developing these abilities in children,

   b) development of teacher judgmental abilities to make intelligent decisions about curricular issues in the face of growing outside pressure for fads and uninformed policy,

   c) recognition that skills of statistical inference and the ability to deal intelligently with collections of information are among the essential minimal skills required by every person in today's world,

   d) appreciation of the uses and applications of mathematics in the solution of "real world" problems,

   e) development of skills in teaching the effective use of computing and calculating machines in solving problems,

f) for secondary teachers, literacy in at least one problem solving programming computer language and grasp of the issues in computer literacy,

g) preparation of new teachers to enter realistically the existing school systems as well as to participate in emerging trends. (9:139-41)

SUGGESTIONS FOR KINDERGARTEN MATHEMATICS TEACHER EDUCATION

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As a result of her extensive research into recent trends of curriculum development, Weber (10:2) has described kindergarten as a "no-man's land" in which not much is happening in the field of education.

Although there has been much activity at the preschool and early primary levels (grades one to three), innovative programs at the kindergarten level have been more an afterthought than a main concern. Many current preschool programs, such as the Follow Through programs which developed as an extension of Head Start, have been designed to be carried over into the kindergarten; while early primary programs, many based on textbook series, often attempt to extend down to the kindergarten level. There are, however, few, if any, specific model kindergarten programs.

As an area of educational specialization, kindergarten has been possessed by no one yet claimed by almost everyone. The kindergarten level is tacked onto several types of teaching certificates. Elementary certification often includes kindergarten as the lowest level. In many states (e.g., Oklahoma), elementary certification includes kindergarten through eighth grade.

This also tends to be true of early childhood education certification which may include nursery school through second or third grade, or nursery school through kindergarten, as in the state of Oklahoma. No matter how they are divided, teacher certification programs often overlap at the kindergarten level.

As a result of overlapping certification, two basic channels or programs for kindergarten teacher education have emerged: (1) elementary education and (2) early childhood education. These programs differ in a number of ways in their approaches to teacher education generally and to mathematics teacher education specifically in terms of (a) their views of the discipline of mathematics, (b) methods of teacher preparation, and (c) teacher products of the programs. These differences result in divergent views of the role of mathematics in the kindergarten.

The elementary teacher education approach often emphasizes mathematics as a distinct discipline and a separate area of the curriculum. This approach encourages future teachers to learn the structure of the discipline and how to teach it using various current methods and materials. The early childhood education approach generally focuses on the child as an area of study and encourages future teachers to understand how children learn mathematical concepts in order to become a facilitator of the process.

These two different approaches are reflected in divergent classroom practices by the two sets of teachers who emerge from the programs. The kindergarten teacher from the elementary program tends to perceive kindergarten as a period of preparation for first grade and a time for children to become serious about the learning process. Priority is placed on learning to sit quietly, to pay attention, and to learn to follow rules and take orders. Play is regarded as an activity for outside school hours or for recess time. Children are often admonished to "act like first graders, not kindergarten babies."

The kindergarten teacher from the early childhood education program tends to extend the goals of nursery school education into kindergarten and views kindergarten as an important time of initial adjustment to school rather than as a period of preparation for a future level. The emphasis is on providing a positive first school experience so that the child will enjoy school and want to learn. Play is perceived as a vehicle for learning.

Other basic differences surely exist in the two approaches and deserve further examination.

Who Teaches in the Kindergarten?

Probably most of the public school kindergarten teachers who are teaching today were trained in elementary teacher education programs. Early childhood teacher education programs are increasing in number, however, and teachers from these programs are being hired more frequently for kindergarten teaching. In some areas where this type of program has gained prominence, public school administrators in charge of hiring are giving preference for kindergarten jobs to teachers trained in these programs. However, this tends to be the exception rather than the general practice. Very often, in order to deal with budgetary problems and decreasing enrollments, elementary teachers and even junior high school teachers are being reassigned to kindergartens in order to keep them employed.

In general, there are basically two types of public school kindergarten teachers: those trained in elementary programs and those trained in early childhood education programs. These two types of teachers differ not only in training but also in methods of teaching.

Differences in Training. Many elementary teacher education programs require a minimum of mathematics courses such as one course in arithmetic for teachers and another course in mathematics methods. The former course may emphasize basic computational skills and may or may not deal with educational applications. The mathematics methods course is usually aimed at teaching at the fourth grade level since certification may be kindergarten through eighth grade. This "happy medium" approach does not teach the student teacher how to deal with the needs and abilities of the kindergarten-aged child. It is taken for granted that somehow the student teacher will know how to "water down" the fourth grade mathematics curriculum to kindergarten level. The result is often disastrous with children and teacher both becoming very frustrated and anxious over mathematics.

Elementary teacher education programs require many discipline-oriented courses (such as social studies and language arts) and tend to neglect or only minimally include child development courses. The major thrust is on the separate disciplines. Future teachers are instructed to teach subject matter rather than children. While this approach may be appropriate for the older child, it is not too beneficial for the younger child who is just learning to be a person involved in the educational process and who needs a supportive adult who understands the young child's needs and capabilities.

In his discussion of the role of the teacher of young children in mathematics instruction, Spodek (9:153) states:

> *Although she needs to be knowledgeable of mathematics and of methods of teaching mathematics, more important is her sensitivity to children.*

Copeland (3) points out that a major problem in training elementary teachers is that they are more interested in teaching subject matter than in teaching children, primarily because their training is in methods and content areas rather than child development.

Some elementary teacher education programs do not provide experiences in working with children until the student teaching experience which usually occurs during the final semester of the program. The recent trend, however, seems to be toward more field-based experiences with children at earlier stages in the program. While this appears to be a worthwhile trend, it would be even more beneficial if the experiences were at a variety of grade levels or at those levels where the student is more likely to be later employed as a teacher. A student teacher whose experiences with children have been in fourth grade or above may find it difficult to relate to the kindergarten-aged child, and this student teacher could very well become employed as a kindergarten teacher. Many elementary education student teachers placed in the kindergarten for student teaching comment that they feel unprepared for the job and frustrated in their attempts to teach subject matter to children who won't "sit still and pay attention."

On the other hand, early childhood teacher education programs tend to emphasize understanding children and how they learn. As a result, many courses in child development and learning are required. Their major thrust is to give students an understanding of the needs and abilities of young children as they pass from one stage of development to another. Their emphasis is on teaching children rather than subject matter. Their aim is to prepare students to better relate to young children and provide for their needs.

Early childhood education programs are similar to elementary education programs in requiring a minimum of mathematics coursework. Early childhood programs, however, often combine mathematics methods with other curriculum areas such as science or social studies. Although this may reduce the total amount of mathematics exposure, it may also demonstrate the interrelatedness of the various curriculum areas.

While elementary education students suffer from the "water down" syndrome, early childhood education students are exposed to the "water up" approach. They are required to apply what they have learned about nursery school children and their instruction to the kindergarten child. This approach may result in activities which are not challenging enough to the older child and in unstructured, unplanned programs.

Early childhood education students are often exposed early in the program to experiences working with young children in university laboratory nursery schools. However, they usually are not exposed to older children until student teaching in the public schools which often occurs during the final semester of the program. These student teachers, when placed in the kindergarten, often comment that they are apprehensive about working with large groups of older children since their experiences have been limited to situations with younger children and lower student to adult ratios. Many have remarked to the author that they feel inadequately prepared in music, science, and mathematics since these areas seem to be less emphasized in their program.

Differences in Teaching Practices. These two approaches to teacher education result in differences in teaching methods and mathematics instruction in the classroom. The elementary education trained teacher concentrates more on teaching content and subject matter which will prepare the child for first grade instruction. The kindergarten teacher may feel pressure from the first grade teacher, parents, or the principal, to have children counting and doing simple arithmetic computations by the end of the year. To accomplish these goals, he/she may use a kindergarten or preschool component of a mathematics textbook series which has been adopted for use in the upper grades. Workbooks and dittoed work sheets are favored to provide mathematics activities and problems. The teacher may attempt to teach the written symbols and verbal labels for numbers from one to one hundred through drill and rote memory exercises. She/he may also set aside a certain period of the day, such as a thirty-minute period devoted solely to mathematics instruction.

The teacher from the early childhood education program may not set aside a specific time of the day for mathematics instruction, but may randomly attempt to incorporate mathematics activities into the day-to-day classroom routines such as having the children decide how many napkins should be distributed for snack or how many children should be allowed to work in a particular activity area. The teacher may also provide a great many manipulative objects for children to sort, classify, or count. The approach tends to be more activity oriented with an emphasis on unstructured play rather than on rote drill of mathematics facts. Science and mathematics instruction are often combined into the same activities, as if by doing science experiments, mathematics is somehow automatically taken care of.

What's Missing? The elementary teacher education approach tends not to provide a basic understanding of children and how they learn as well as an exposure to materials and activities appropriate for the kindergarten level. The early childhood teacher education approach tends not to provide sufficient instruction

in the area of mathematics and in planning mathematics programs for kindergarten children. Both are lacking in providing enough field-based experiences working with kindergarten children early in their programs. Both would probably be strengthened by providing increased exposure to the application of mathematics instruction in the kindergarten classroom.

Which approach, if either, is more educationally sound? Which approach, if either, is more appropriate for teaching how to provide initial exposure to mathematics learning? Which approach would do more to prevent or alleviate learner anxiety toward mathematics? Which approach would better prepare individuals capable of thinking in new ways and solving problems which may confront them in the future? These are difficult but important questions which will remain unanswered until the necessary educational research has been conducted. Much may be gained, however, by an examination of the kindergarten level and the characteristics of kindergarten-aged children. Implications may then be drawn for the improvement of teacher education programs in general.

Kindergarten as Transition

The idea of the kindergarten or "children's garden" was adopted from the German model established by Friedrich Froebel during the 1800s. It was brought to America in the late 1800s and began to flourish during the early 1900s. Only recently, however, as a result of legislation has kindergarten become mandatory in most states.

During its existence, the kindergarten has gone through many changes and social reforms. Today it is generally considered an integral part of most public school systems and provides the first school experience in formal education for many children.

Kindergarten is a misunderstood level probably because it represents so many transitions and changes for the child. It is a period of transition (1) from the home to the school; (2) from parent influence to peer influence; and (3) from limited motor, social, and cognitive skills to the development of increased skills.

While kindergartens are a part of most public schools, they tend to be separated physically from other classrooms, often located at extreme ends of the building or in separate buildings or temporary cubicles. Many schools even provide a separate playground area for kindergarten children. As a result of these factors, kindergartens tend to become isolated from the daily routine of the school.

Although there are many all-day programs, most kindergarten programs are composed of two half-day sessions for separate groups of children. For various reasons the younger children usually attend the morning sessions. Curriculum content varies from school to school but tends to range from highly academic, with a concentration on reading and mathematics instruction, to highly social and unstructured, with a concentration on "free play" experiences.

Characteristics of the Kindergarten Child. The kindergarten child is usually between five and seven years of age, and in most school districts must have reached the age of five on or before the first of November of the school year in order to attend. According to Piaget's periods of cognitive development (8), the kindergarten-aged child would be beginning the transition from the preoperational to the concrete operational level. Because of individual differences, however, all children in the same classroom will probably not be at the same level of cognitive development simultaneously. Some children will be at the sensorimotor level, others at the preoperational level, and a few at the concrete operational level. This is why individualized instruction is so important at the kindergarten level. Children from a variety of backgrounds bring a variety of experiences to the classroom. Some kindergarten children may be able to read, recite numbers, verbalize their ages, and even conserve number. Others will not be able to do these things until they have the appropriate maturation and learning experiences.

In general, kindergarten children tend to be highly enthusiastic about school, intrinsically motivated to learn, and eager to please the teacher. However, they also tend to be egocentric, viewing the world from one perspective–their own (7).

How Children Learn. Young children learn by doing (2, 7). Their learning is active and should engage them in challenging experiences with concrete objects which represent physical reality (6). Learning proceeds from the concrete to the abstract. Children learn about concepts through interacting with the environment and with other people. Abstract thought is not developed until the period of formal operations which begins around age 11 (8). Until then children are bound to the physical world and respond to learning activities which make use of physical objects and activities (9).

According to Copeland (3:208):

> *Children in the elementary school, however, are not ready to work at the abstract level with formal logic and proofs. They are very much a part of the physical world. Mathematics for them should be exploration and discovery–an inductive approach through the physical world with concrete objects.*

Copeland provides many valuable suggestions for teachers based on how children learn rather than on how to teach subject matter. He has drawn implications from Piaget's research concerning children's cognitive development. For example, he says that elementary teachers work with children at the concrete operational level and that logic activities should be introduced only as they relate to objects in the physical world. Therefore, the use of workbooks which are two-dimensional representations of reality are not appropriate for the preoperational child who needs hands-on experiences with concrete, three-dimensional objects. For example, some mathematics workbooks are designed for the kindergarten level containing punch-out cardboard discs representing pennies, nickels, dimes, and quarters used to teach money and counting concepts. While the use of these tokens is probably better than mere pictures of the objects, they do not adequately represent real

coins and are often not the actual size of real coins. These tokens can be quite confusing to the young child who has had limited experiences with money and may not yet be able to conserve number much less understand such abstract notions as five nickels make one quarter. Why not use real coins and minimize the confusion?

In his discussion of the content of mathematics programs, Spodek (9:139) stresses that

> *teachers of young children can plan many fruitful mathematics experiences without recourse to textbook or to lecture and recitation sessions.*
>
> *. . .The endless opportunities available in any classroom for counting, comparing, and measuring, provide children with a wealth of opportunity to do mathematics.*
>
> *These experiences with real things in the children's environment, if used appropriately, can keep children from feeling that mathematics is something strange, totally theoretical and completely alien to their lives, a feeling that can be communicated when mathematics is taught in a rigid, totally abstract way. . . .Often it is the way mathematics is taught rather than mathematics itself that creates learning difficulties.*

According to Piaget (8), most children do not conserve number until around age seven or eight. Yet it is often assumed that the child who can recite numbers from one to ten has also developed the underlying concept of number.

Piaget stresses (8:144) that

> *. . .the child may be taught to count, but experiment reveals that the verbal use of the names of numbers has little connection with numerical operations as such, which sometimes precede counting aloud and sometimes follow it, with no necessary bond between the two.*

Spodek also maintains that verbal counting in kindergarten is often accepted for basic understanding (9:141).

> *What too often passes for counting is the ability to recite the names of numbers in sequence without any understanding of the idea of the number that corresponds to a given name or numeral.*

We should never mistake rote learning for basic understanding. Yet much of what passes for mathematics in the kindergarten are activities in rote memorization. This can be seen in the emphasis on teaching the calendar and clock time. While memorizing days of the week in order may in some way be a justifiable learning experience, it is not an indication that the child understands the concepts of days or weeks or months as units of time.

The "back to the basics" slogan has become a very popular one recently. At the kindergarten level, it would probably be more appropriate to "go forward to the basics" since basic concepts such as number have never really been greatly emphasized in kindergarten. Perhaps if we are really interested in "going back to the basics," we should begin at the kindergarten level by replacing the emphasis on rote learning of verbal number names with an emphasis on developing a "basic" understanding of the concept of number before requiring children to perform more abstract number operations.

Suggestions for Teaching. Kamii and De Vries (4) provide some valuable principles for teaching number based on Piaget's research. Three of these principles include teaching number concepts when useful and meaningful to the child; figuring out how children are thinking; and encouraging children in a general way to put all kinds of objects, events, and actions into relationships. They point out that

> *Cuisenaire's approach to teaching number with rods reflects the common confusion between discrete and continuous quantities. For Cuisenaire, the 1-cm rod stands for "one," the 5-cm rod stands for "five" and the 10-cm rod stands for "ten." For Piaget and most young children, however, each of these rods can only be "one," since it is a single, discrete object. Number involves the quantification of discrete objects, and therefore cannot be taught through length which is a continuous quantity. (4:16)*

Other specific suggestions for teaching mathematics in the kindergarten based on the knowledge of how children learn can be found in Copeland (3). In addition, the Thirty-Seventh Yearbook of the National Council of Teachers of Mathematics, *Mathematics Learning in Early Childhood,* is an excellent resource for current research, activities, and materials (5).

An outstanding example of a mathematics program designed for public school kindergarten children based on their natural ways of learning was implemented during the 1976-77 school year by Dr. Alberta M. Castaneda of the University of Texas at Austin. Currently Dr. Castaneda is extending her program at the first grade level and has plans for publication of the results of her project at a future date. This mathematics program is based on concept development and oral language use. She maintains that before children can read, write, and do mathematics, they must be able to "talk" mathematics and verbalize the meanings of symbols before they write them. The concept of number does not exist in the real world and must be developed from within before the child is given the written symbol. Dr. Castaneda emphasizes building meaning through concept development and oral language acquisition. She has devised a number inventory to assess number concepts in five-year-olds. She has also designed a sequence of activities for teaching based on the child's development of number concepts. One interesting finding of the project is that kindergarten children performed better on the number inventory when objects were available for manipulation during testing. Dr. Castaneda stresses the importance of developing the basic number concepts before progressing to more abstract manipulations.

In summary, seven suggestions for teaching mathematics at the kindergarten level include:

1. *Figure out where children are developmentally through observation of self-selected activities and questioning techniques.*

2. *Match the materials and activities to each child's level of development.*

3. *Use manipulative materials which are appropriate learning materials for all levels of development.*

4. *Integrate mathematics learning throughout all areas of the curriculum making the whole classroom into a mathematics laboratory.*

5. *Capitalize on the child's intrinsic motivation to learn by providing activities based on each child's interests.*

6. *Capitalize on the child's tendency to interact with other children and use this for grouping or pairing children during problem-solving activities. The use of mathematics games and activities involving two or more children enhances role-playing development as well as mathematics learning.*

7. *Use everyday experiences such as the distribution of materials to teach number concepts.*

Suggestions for Teacher Education Programs. In general, teacher education programs which prepare kindergarten teachers should at least provide some experiences for students to work with kindergarten children so that they will better understand that kindergarten is a unique time for children to learn certain things rather than a training or drill time for a higher level.

Teacher education programs should strive to expose students earlier to working with children at a variety of educational levels so that students will better understand that the developmental process is a continuous one. Many programs are attempting to do this through classroom observational experiences during the sophomore and junior years. While early observational experiences are worthwhile, they become much more valuable when students are guided through use of observational instruments, or follow-up discussion seminars, or assignments in which students actually plan activities for and interact with young children.

Although students in teacher education programs should probably be required to take more courses in mathematics, often this is an unreasonable goal because of the many other necessary degree and certification requirements. However, attempts should be made to improve minimum course requirements to make them more relevant and useful. One suggestion would be to provide a variety of mathematics methods section options for those interested in early primary grades and

for those interested in later elementary grade levels. As a result, methods courses could be designed for instruction at a more appropriate level based on student interest rather than on the current "happy medium" fourth grade level to which all students are exposed. Courses in arithmetic for teachers could be made more relevant through emphasis on the practical application of teaching computational skills through assignments in which students actually work with children as tutors or instructors.

Either through mathematics coursework or methods instruction, students should learn to understand the interrelatedness of the various curriculum areas. In an attempt to provide adequate instruction, we have often presented the various disciplines as isolated segments. A more interdisciplinary approach is needed to show the relation of mathematics to other curriculum areas such as science or music. In this way students would perceive learning not as fragmented bits of information but as a unified whole. Mathematics has traditionally been taught at all levels as an abstract body of knowledge. We can no longer afford to do this. Rather we need to approach mathematics education as a useful survival tool with practical application to everyday life and the furtherance of creative ideas.

Finally, one of the most important suggestions for teacher education programs which prepare kindergarten teachers is to refocus on the importance of understanding children and how they learn mathematics concepts. Until we as teachers understand the developmental learning process, we cannot hope to implement worthwhile mathematics programs for young children which take into consideration how they develop mathematics concepts. A concentration on the social transmission of mathematics "facts" will continue to produce individuals who have memorized formulas and information just to get by, who have not adequately developed the basic underlying concepts, and who as a result are anxious about mathematics.

Five general suggestions for improving teacher education programs can be summarized as follows:

1. *Increase and/or improve mathematics course requirements so that they are more relevant to educating the young child.*

2. *Expose students earlier in the program to actual implementation of kindergarten mathematics programs and to working with younger children.*

3. *Stress the interrelatedness of the curriculum by showing the relation of mathematics to other curriculum areas.*

4. *Encourage the understanding of the use of mathematics education as a practical survival tool rather than as an abstract body of knowledge.*

5. *Place major emphasis on understanding young children and how they develop mathematics concepts.*

Conclusion

Kindergarten has been a misunderstood and neglected area of teacher education. It is time to rethink the importance of this level as a special time in itself in which *all* children are "ready" for some type of mathematics experience. The "no-man's land" of the kindergarten needs to be developed into a state of its own and valued for its significance as an initial introduction to the formal educational process.

If it is true that the early years are the most important in setting the stage for learning, and if it is true, as Piaget (1) states, that

> *the principal goal of education is to create [humans] who are capable of doing new things, not simply of repeating what other generations have done. . .[humans] who are creative, inventive, and discover. . .*

then we can no longer afford to continue the approach of social transmission of mathematics facts to young children. Kindergarten mathematics programs and teacher education programs must take into consideration how the young child learns; they must stress the need to capitalize on the young child's intrinsic motivation to develop mathematics concepts as well as the need to facilitate the development of the capacity for inventive thought.

THE ANSWER TO THE PROPHETS OF DOOM: MATHEMATICS TEACHER EDUCATION

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Change

"Students in our schools today are unable to solve the simplest math problems." "Test scores are steadily getting lower." "Students are graduating from our schools not being able to add, subtract, multiply, or divide." "Children today cannot handle a fractional number." "College students cannot do a basic mathematics computation." These statements appear daily in our newspapers and on our TV screens and radios. They reflect the concern of parents, administrators, and the general public. Changes have been made in textbooks, syllabi, and even in the physical design and facilities of schools. But they have effected little change in student performance. If there is to be an improvement in students' mathematics performance in the primary, elementary, and secondary schools, it will be the result of changes made in teacher education institutions. *"Quod non habet, non potest dare"* (What you do not have, you cannot give) is the striking reality existing in many classrooms today.

Rationale

Historians predict that unless we examine and learn from the past we are condemned to relive it. It appears that their prediction may be in the process of fulfillment in the area of mathematics education.

In 1957, the launching of Sputnik drew the spotlight of examination to the performance of students in the science and mathematics classrooms of our schools. Their performance was below public expectations. Cries of indignation arose and were brought to us through the news media. In the area of mathematics, educators proposed the "new math" as the elixir which would improve performance. The "new math" was introduced with great haste, a magnificent "press," and little teacher preparation. Textbooks were advertised featuring the "new math" approach. School systems adopted textbooks based on advertised claims and pointed to them as proof that an effort was being made to improve children's mathematical performance. When there was no significant improvement in student performance, educators began to question the validity of the principles of the "new math." In its recent report, the National Advisory Committee on Mathematical Education (NACOME) affirmed that the "new math" is sound in principle but that its implementation had been poor. The "new math" had not been tried and found wanting; it had not really been tried.

Twenty years later low student scores reported on standardized tests again drew the spotlight to the poor performance of students in the mathematics classroom. Again, the news media gave great attention to the public cries of displeasure.

And, again, a remedy has been proposed–this time in the form of the back-to-basics and competency-based education movements. Textbooks featuring the back-to-basics approach have appeared on the market, and states are legislating competency examinations in elementary and secondary schools. Again, we are moving with great haste, a magnificent "press," and little teacher preparation.

We continue to treat the symptoms rather than the disease. When children are unable and unwilling to learn mathematics this is a symptom that mathematics is not being taught in the manner in which children learn. Preparing teachers to teach mathematics is the responsibility of teacher education institutions. It is to these institutions, therefore, that we look for leadership in curing the disease and in assuring the future mathematical health of students.

"It is essential for teachers to know more than they are expected to teach and to be able to learn more than they already know, for without such knowledge progress is essentially impossible." (2:5) In the cognitive area we need a teacher education curriculum which assures knowledge and competency in mathematics as well as a knowledge of the philosophical, historical, psychological, and sociological aspects of education. In the affective area we need a stimulus for the growth of teachers' ability and desire for knowledge.

Math Anxiety

The mathematics courses presented to future teachers in pre-service training need to be fashioned not only to provide solid mathematical content; they also need to be presented in a manner which will help future teachers overcome math anxiety. Possibly one of the most serious handicaps of prospective teachers, especially those preparing for careers in primary and elementary schools, is their fear of mathematics. Many are honest enough to admit to some degree of anxiety where mathematics is concerned. Some will admit that they never really understood mathematics and that they are convinced no amount of practice or drill will help them. Some have always memorized rules and procedures and been able to perform satisfactorily, but they now realize that that is an inadequate preparation for teaching mathematics. Math anxiety can also be inherited. A parental comment regarding a failing or poor mathematics grade is frequently, "I never understood or liked math when I was in school either."

Math anxiety may have cultural roots. Women in our culture have not been expected to excel in mathematics. Little attention has been given to the difficulties they experience in learning the subject since the "mathematical mind" has been considered a male attribute. Women, therefore, are prime candidates for mathophobia. Yet female teachers constitute the majority in primary and elementary schools. They cannot be expected to generate enthusiasm and excitement for a subject for which they have fear and anxiety. If the cycle of mathophobia is to be broken, it must be broken in the teacher education institution. The fears of both male and female teachers need attention.

With the assistance of a grant from the Fund for the Improvement of Post-Secondary Education (Department of Health, Education, and Welfare), Wesleyan

University in Connecticut has opened a "Math Anxiety Clinic." Its purpose is to serve undergraduates who admit that they cannot cope with their math fears and difficulties. The clinic interviews and diagnoses students and provides therapy and counseling in a nonthreatening, supportive, personal atmosphere. Here the psychological or emotional causes of math anxiety can be determined and treated.

Similar clinics which would also deal with the cognitive aspects of mathematics anxiety would be a welcome addition to the teacher education program. An important function of the math clinic would be to persuade teachers, learners, and those who make educational policy that "mathematical abilities are accessible by the majority, if properly taught and if accompanied by the right kinds of support." (6) These clinics would serve the future teacher by strengthening individual mathematical weaknesses and filling in the gaps of the teachers' mathematical background. The emphasis would be on understanding mathematical concepts, operations, and procedures.

Individualization

Our philosophy of education in the past was based on the liberal arts. At present we have a philosophy of education which could be termed "economic" since we are ever concerned with the economy of time, effort, and finances. There are indications all around us that the educational philosophy of the future will be humanistic. The curriculum will be individualized with special attention given to the unique goals and needs of each learner. As individualization becomes a more prominent element in the mosaic of education, teacher education institutions must begin to teach the observational techniques by which a child's individual cognitive style can be determined. Such a determination will not only allow learning experiences to be customized for the student by the teacher, but it will also give the child the self-knowledge to allow a choice of activities in the cognitive modes best suited to each learner.

Teachers will need to know the language and symbolism required to prepare, interpret, and utilize the child's cognitive map. They will need to diagnose the strengths and weaknesses of each child and to communicate phenomena and problems in exact and precise terms. Teacher education curricula will need to include some form of educational science, i.e., symbols and terminology similar to the cognitive style mapping symbols and their meanings pioneered by Dr. Joseph Hill of Oakland Community College in Bloomfield Hills, Michigan (4).

Another related phase of individualization is the diagnosis and prescriptive remediation of a student's mathematical difficulties. A harbinger of this thrust was the initiation in 1977 of a national organization of educators, the Research Council for Diagnostic and Prescriptive Mathematics. Teacher educators need to be attentive to the work of this organization so that they may incorporate into their programs the techniques and procedures needed by classroom teachers to successfully determine student difficulties and to prescribe effective remediation.

Learning Theory

Models of mathematics methods courses are as varied as the number of teacher education institutions in which they are taught. A common denominator among these methods courses should be the translation of the research results of learning theorists into teaching methods. Yet, although the names of Piaget, Gagné and Bloom are familiar to most teachers, and their theories are explained and discussed, there is little evidence of the application of these theories in the classroom. Primary and elementary school teachers have attempted to apply these theories to some degree; but the as yet unmet challenge is the implementation of these theories in secondary school mathematics methods courses. Across the nation we find the lecture method prevalent in secondary school mathematics classrooms. Students remain passive. Jean Piaget spoke to this situation when he addressed the Second International Congress on Mathematical Education at the University of Exeter in 1972: "It would be a great mistake, particularly in mathematical education, to neglect the role of actions and to always remain on the level of language. . . .Activity with objects is indispensable to the comprehension of arithmetical as well as geometrical relations. . . ." (5:80) We have seen little change in secondary school mathematics methods courses resulting from this statement.

Although some educators complain that educational research is concentrated on young children and little of it is applicable to secondary school students or to adults, Robert Gagné makes the point that learning is a human activity which occurs from the cradle to the grave. As he defines it, "Learning is a change in human disposition or capability, which can be retained, and which is not simply ascribed to the process of growth." (3:8) The conditions of learning presented by Gagné are not unique to children but are applicable to all learning. We may discuss these conditions in our learning theory class, but we have not allowed them to penetrate the mathematics methods courses.

A frequently overlooked element in teacher education programs is the technique of questioning. This technique is obviously important to the guided-discovery approach. Little attention, however, has been given to the level of questioning in the classroom. Utilizing Bloom's taxonomy, the knowledge, comprehension, and application levels of questioning occur frequently in the classroom (1:271-77). The analysis, synthesis, and evaluation levels of questioning are seldom demonstrated or examined in education courses and therefore remain unused in the classroom.

Clinical and Field-Based Experiences

Early clinical and field-based experiences for teacher education students must be an integral part of the teacher education curriculum. The future teacher, under direction and supervision, needs a variety of experiences with children. Regrettably some teachers have their first contact with children in a professional role when they begin their student-teaching experience. This is too late. The teacher needs to have such experiences in a one-to-one tutorial situation, and in

both small group and large group teaching situations early in the teacher education program. Experiences with children need to be frequent and graduated in the degree of responsibility placed upon the teacher education student. As in the introduction of some new teaching-learning tool in the classroom, "free play" time is important; such time should be given to the future teacher to spend with children.

Children may be found at laboratory schools such as the University School on the campus of Kent State University in Kent, Ohio; or in elementary schools in the area surrounding the campus as in the Methods Experience Project at Bowling Green University, Bowling Green, Ohio. Where such facilities are not available, children from the families of teachers and faculty members could be brought to the campus. However it is done, early clinical and field-based experience for the prospective teacher must be provided.

Faculty

The Guidelines for the Preparation of Teachers of Mathematics states, "All faculty members should have the knowledge, competencies and attitudes described in the foregoing sections, entitled 'Academic and Professional Knowledge' and 'Professional Competencies and Attitudes.'" (2:23) This directive is usually followed religiously. The following sentence, however, although equally important, is too often ignored: "They [all faculty members] should have appropriate continuing experiences in schools." (2:23) When this recommendation was mentioned at a recent national meeting of the National Council of Teachers of Mathematics, the speaker drew enthusiastic applause from the teacher-audience. The implication would seem to be that teachers feel that their professors in teacher education institutions are out of touch with the realities in the field; that there is still a wide gap between what is taught in the education classroom and what is happening in the primary, elementary, and secondary school classroom. A somewhat revolutionary but effective means for keeping the teacher education faculty in touch with these realities would be a required one-semester professional furlough provided every five years. Such a semester would be spent by the faculty member teaching in an elementary or secondary school. A periodic return to the "front lines" would be an enrichment experience for the faculty member. It would also deepen the faith of the teacher education student in the faculty.

Evaluation

Finally, an essential element of a vibrant, relevant, and effective teacher education program is formative evaluation. "The faculty of a teacher-education institution should. . .plan programs to evaluate the graduates of the teacher-preparation programs with a view to improving those programs through long-range planning based on continued evaluation." (2:28, 29) An important aspect of this evaluation would include "the advice of all individuals interested in improving schools (including experienced teachers, administrators, university faculty members, students, and other citizens). . ." (2:28) It is encouraging to note that the recently released position statement of a joint committee of the Mathematical Association

of America and the National Council of Teachers of Mathematics was based upon the strongest consensus of consultations with secondary school and college teachers in various parts of the country (7). Hopefully there will be future examples of such collegiality.

Conclusion

We will continue to be challenged by critical statements in the press; stopgap measures will be taken to attempt to pacify the public; but students' classroom performance may not improve. Our hope lies in the education community and its willingness to work for, accept, and support the changes which must be made in teacher education institutions.

SPECIFICATIONS FOR THE TRAINING OF A TEACHER OF GENERAL MATHEMATICS IN JUNIOR AND SENIOR HIGH SCHOOLS: A Recommendation of the Michigan Council of Teachers of Mathematics Directed to the Teacher Training Institutions of Michigan

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In the 1972-73 and 1973-74 school years, a seventeen-member committee of the Michigan Council of Teachers of Mathematics (MCTM) worked at length to develop specifications for a Teacher Training Proposal which would deal with certain assumptions. The proposal, which is presented in this chapter in its entirety, is based on these assumptions:

1. The single most important skill in mathematics remediation work is the ability to help students to read a mathematics book. Hence, a course, or courses, in diagnosis and remediation of reading deficiencies is a must for pre-service secondary mathematics teachers.

2. Every secondary mathematics teacher can expect to teach several sections of general mathematics classes, particularly during the first years of teaching. Further, with large numbers of teachers being hired in large urban school districts, it is important for pre-service teachers to spend time in urban general math classes with large numbers of minority students and many students who are disinterested and who may be discipline problems.

3. The college mathematics classes most valuable to many senior high and to all junior high mathematics teachers are the content methodological work and the pre-calculus level mathematics classes. Further, new content areas, including probability and computer programming, are more important in high school mathematics work than the traditional calculus-analysis classes.

4. Many elementary teachers do a better job of *teaching children, managing multiple groups* for instruction, and *taking into account* the *psychological needs* of the students in their care than their peers who are teaching secondary mathematics. Hence, pre-service mathematics teachers should spend some time in upper elementary classrooms learning the teaching and management skills possessed by these elementary teachers.

5. Not only do pre-service teachers need to spend time in elementary classrooms, but they need to spend *more time* than the traditional one term/semester student teaching model in classrooms of the type they expect to teach. Our committee concurs with the NACOME report (1:88) *that earlier field experience be incorporated into* pre-service teacher education *programs.* In fact, our report specifically recommends 345 clock hours of pre-service contact with students in

elementary, junior high, and senior high school math classrooms, for sophomore, junior, and senior level mathematics education majors.

6. Since the value of pre-service experience will depend heavily on the competence of the cooperating teacher in the school and the recency of experience of the university personnel who coordinate and follow up these pre-service in-school experiences, there is a need to carefully describe these people from a quality and experiential point of view. Our report speaks to this recency of experience of university teachers and coordinating staff in K-12 classrooms of the level and type in which their students will be working. We have named these staff positions "Clinical Professors."

In addition to these assumptions, the committee presented the following overview to the MCTM Teacher Training Proposal:

> *Teacher training in mathematics requires, and will continue to require, many more hours of clinical experiences for the pre-service student. By clinical experiences is meant on-the-job exposure to real students at the grade levels the pre-service students are preparing themselves to teach. These experiences are made necessary by a great increase in the number of students whose motivation to learn mathematics is significantly less than that of students in the mathematics classes in junior and senior high school of which the prospective teacher was a member.*
>
> *To support the additional hours of clinical experiences, the student should have a university staff member who has recent experience in the elementary, junior high, or senior high classes, which his/her classes are addressing. Further, there will be a need to reduce the number of pure mathematics classes to be completed by the student, at least at the required level, to make time available for these clinical experiences.*
>
> *The Teacher Training Proposal makes specific suggestions concerning the structuring of the clinical experiences and scheduling of pure mathematics classes to make time for the clinical experiences.*

The remainder of this chapter is devoted to the report as it was adopted by the MCTM Executive Committee in the spring of 1974 and as it was widely disseminated to teacher training institutions and professional groups of mathematics teachers in Michigan and neighboring states.

Introduction

Most teachers of Secondary Mathematics, grades 7-12, spend the majority of their teaching hours working with students other than those studying Second Year Algebra, Analysis, or Advanced Placement courses.

Nearly all teachers will have at least one General Mathematics class each year of their teaching career.

Each year a greater number of schools encompass an urban population, or one from low socio-economic areas, and/or minority groups. Hence, it is appropriate that teacher training provide experience in these types of settings. For these reasons, we propose the following teacher training program for secondary teachers in mathematics.

I. Clinical Experiences

A. Each student in this program should participate in carefully supervised Clinical Experiences. These experiences will be under the supervision of a Clinical Professor of Mathematics Education, and they will be conducted within a public school but designed to be of value to the trainee, the students of the public schools and the sponsoring university. These experiences should include, but not be limited to, the following components:

1. Tutorial Experiences (1-1 teaching)

2. Small Group Experiences

3. Total Class Teaching Experiences.

At least one of the total class teaching experiences should be in a secondary school with a large proportion of children who come from a low social and economic environment.

B. Clinical teaching experiences will be arranged so that the trainee has experience with students at each of the following levels:

1. Grades 3-6

2. Grades 6-9

3. Grades 9-12

   a. in a general mathematics class

   b. in college preparatory mathematics classes.

C. A recommended time schedule for the trainee's clinical field experiences is:

Min. Clock Hrs.	School	Level	Experiences
25 hours	Elementary	3-6	Tutoring or small group instruction
120 hours	Middle or Jr. High	6-9	Tutoring or small group and total class
120 hours	Senior High	9-12	Tutoring or small group and total class
*200 hours	Secondary	7-12	Total class and tutoring small group
345 hours total			

*Includes one of the two secondary experiences listed above, or a combination of them.

D. The clinical experiences program will be evaluated on a periodic basis by the MCTM Teacher Training Committee, based on a campus visitation. A report of this evaluation will be furnished to the participating institutions. When necessary, recommendations for the improvement of the program will be made by this committee.

II. Minimum Required Courses **Suggested Sem. Hrs.**

A. TEACHING OF ELEMENTARY MATHEMATICS (K-6) 3 hrs.

Effective techniques in presenting materials, planning class activities and creating good learning experiences; current problems in a modern mathematics curriculum, for this level.

1. Methods and Structural Content
2. Learning Theory as applied to Elementary School Mathematics
3. Laboratory in the construction and use of teaching and learning aids
4. Geometry and Number Concepts

B. READING PROBLEMS IN THE SECONDARY SCHOOL 3 hrs.

This will be a general reading course, but at least a segment of it will be devoted to the problems associated with reading in mathematics.

C. **EDUCATIONAL PSYCHOLOGY** 3 hrs.

This course should point up the type of problems common to most learners at specific age levels and emphasize principles and procedures that will be helpful in dealing with these problems.

D. **TEACHING OF GENERAL MATHEMATICS (7-9)*** 3 hrs.

Effective techniques in presenting materials, planning class activities and creating good learning experiences; current problems in a mathematics curriculum for this level.

1. Methods and content structure
2. Learning theory, as applied to remedial mathematics
3. Geometry
4. Laboratory in the construction and use of Teaching and Learning aids

E. **PROBABILITY AND STATISTICS** 3 hrs.
(not necessarily dependent on calculus)

This course is to be taught experimentally—probability experiments should be performed, data should be collected and analyzed, and inferences drawn by the students. Some consideration should be given to ways of presenting these topics meaningfully in the middle school/general mathematics class.

F. **MODERN ALGEBRA** 3 hrs.

G. **ELEMENTARY NUMBER THEORY COURSE FOR TEACHERS** 3 hrs.

Topics in the theory of numbers which have relation and application to the learning experiences of students at the elementary and secondary school level. Such topics will include:

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*These courses are sometimes taught above grade 9.

1. Ancient and unusual systems of numeration
2. Indeterminate problems
3. Properties of primes, figurate numbers, etc.
4. Diophantine problems
5. Pythagorean Theorem
6. Modular arithmetic

H. COMPUTER USE IN MATHEMATICS — 3 hrs.

This might include:

1. The effect of the Computer on Society
2. The development and function of the Computer
3. CAI
4. CMI
5. Problem Solving
6. Computer Science
7. Simulation
8. Flow Charting
9. A Programming Language

I. MODERN GEOMETRY (a survey course) — 3 hrs.

A survey course to include Euclidean Geometry from the synthetic and transformational point of view as well as finite and non-Euclidean geometries.

III. Recommended Courses

A. HISTORY OF MATHEMATICS — 3 hrs.

B. LINEAR ALGEBRA — 3 hrs.

C. CALCULUS — 4 hrs.

D. TEACHING OF HIGH SCHOOL MATHEMATICS (9-12) — 3 hrs.

E. LEARNING DISABILITIES — 2 hrs.

IV. University Staffing and Structure

A. Mathematics Content Teacher

1. A member of the mathematics faculty

2. Will teach the mathematics content courses, such as Calculus, Linear Algebra, and Modern Geometry.

B. Clinical Professor of Mathematics Education (CPME)

This professor shall have a mathematics background equivalent to at least a master's degree, and shall have special assignments which give him regular experience with K-12 students. He engages in regular classroom teaching in the environment for which his trainees are being prepared to teach. The Clinical Professor's teaching assignments may include such activities as:

1. Trying out experimental materials on a regular basis with children

2. Developing and participating in laboratory activities with children

3. Conducting action research with children.

The Clinical Professor may be a K-12 teacher, under contract to a school district.

It should be understood that sporadic demonstration teaching or occasionally making a presentation to a school class or club does not satisfy the conditions of these assignments. The aim is that the Clinical Professor is in contact periodically with a group or groups of children on a sustained basis. His contact with a particular group of children should continue through a natural cycle in the school year, such as a marking period, a quarter, a semester, or a year.

This activity in the school classroom must have taken place within the last five years to insure his currency and familiarity both with current trends in education and with problems, attitudes, and interests of current children. A minimum of 10 percent of the Clinical Professor's time *within the past five years* must have been devoted to such activities.

A faculty member who does not satisfy the K-12 teaching experience criterion and who wishes to qualify as a Clinical Professor of Mathematics Education shall be considered for qualification upon implementing a plan which will meet the requirement. This plan must be completed within five years.

Examples of combinations of assignments that satisfy such classification are:

Within the most recent five-year period, the Clinical Professor participates in one of the above ways in an appropriate K-12 situation for at least:

1. One semester full time, or
2. One year half-time, or
3. Two years one-quarter time, or
4. One and one-half years for two periods per day, or
5. Two and one-half years for one period per day.

The Clinical Professor of Mathematics Education shall be responsible for teaching:

1. TEACHING OF ELEMENTARY MATHEMATICS (K-6)
2. TEACHING OF GENERAL MATHEMATICS (7-9)
3. TEACHING OF HIGH SCHOOL MATHEMATICS

C. Professor of Special Content-Methods Courses (PSC-M)

This professor shall have a mathematical background equivalent to that of the CPME. He shall also have special interest, experience, and competence in the special courses he is called on to teach. In particular, he shall have the ability to present the material in these courses with appropriate "flavor" so that future teachers will be able to apply their knowledge to teaching children in a manner similar to the way they have been taught.

This professor shall have the responsibility of teaching those courses that are neither background content, nor solely teaching methods, but are a blend of these.

Included are:

1. HISTORY OF MATHEMATICS
2. NUMBER THEORY
3. PROBABILITY AND STATISTICS, and perhaps
4. COMPUTER USE IN MATHEMATICS

COMMENTS ON A K-12 IN-SERVICE COURSE*

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"These kids don't know any math at all. What do those teachers do down there?" This common complaint is heard at all levels—middle school, junior high school, senior high school, even college. An important aspect of mathematics teacher education which rarely gets adequate attention is articulation of elementary and secondary programs. This chapter deals with a description of a graduate in-service workshop course, *Perspectives in Mathematics Education K-12,* in which elementary and secondary teachers explore mutual concerns and issues regarding the teaching of mathematics. Most elementary teachers know little, if anything, about the mathematics programs their students will move into next. Secondary teachers tend also to be unaware of current content and practices in elementary mathematics programs. It seems that formalized opportunities for dialogue among teachers at different levels are needed to provide a setting in which teachers can gain a broader perspective of the entire K-12 mathematics experience, and thus develop a better idea of how the part with which they work fits into the whole. Such opportunities also allow the realization that many issues and trends transcend that wide, imagined gulf between elementary and secondary schools.

With these considerations in mind, a graduate level workshop course was designed. It provides a forum for in-service elementary and secondary mathematics teachers to share their experiences and concerns while studying issues and trends in and materials for the teaching of mathematics. This course helps teachers recognize many common concerns and problems in the teaching of mathematics at all levels, regardless of actual content taught. It also gives some appreciation of the details of sequence and the place of each teacher's efforts in the entire mathematical experience a student may encounter in school.

Individual class members' interests, experiences, frustrations, and access to resources affect the focus of the course which has been somewhat different each time it was taught. Another factor is the ratio of elementary and secondary teachers; the goals were best met when there was a fairly even mix. On the basis of the title, this mathematics education course is likely to attract secondary teachers. Elementary teachers who really know the sequencing of elementary programs and the difficulties children have are also important members of the group. Their testimony is very convincing to secondary teachers who tend to gain a new respect for the complexities of teaching elementary school mathematics and for the large number of skills which its teachers developed.

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* The author was involved with this course while an assistant professor in the Division of Educational Studies at the State University College of Arts and Science, Geneseo, New York.

The course begins with a session to establish the concerns of class members. Each time the course was taught, almost all the topics predicted by the instructor were expressed in some way in the questions and issues raised. A compilation of some of these questions and topics is included.

Regarding the modern versus traditional question–

- Why modern math?
- How much experimentation was done before the new math was accepted?
- A problem in secondary schools seems to be that students do not even know basics!
- How much math theory should kids have as opposed to rote learning?
- Why should the student know the reason for everything?
- What's wrong with memorization? Why won't the answer to "why" come later?
- Why isn't it acceptable to use fingers or count dots if a child can achieve the correct answer?
- Why don't kids know basic facts after eight years of school?
- Why can't kids learn how to divide (division theory, mental division)?
- Why do we teach different bases (base 5, base 2, etc.)?
- How can one relate math to other areas such as physical education, music, and art?

Regarding individual needs–

- A dilemma when students are heterogeneously grouped: If one lets the upper track students work independently (learn class work and extra) and get used to being motivated instead of being slightly bored, there is the danger of being greatly bored in the next grade (when they will be made to work with the class relearning what they learned independently). It seems the only alternative is to just let them continue to be slightly bored and unmotivated all the way through school!
- How do you motivate the older kids? the slower students?
- How might one go about setting up and developing an independent study math lab?

- How do you set up a program of individualized instruction? for enrichment? for slow learners? What materials and resources are available?
- Is there a value in departmentalizing in elementary schools?

Regarding curricular organization–

- Do math texts expect children to have other skills, such as reading?
- A problem with the state achievement tests for elementary school mathematics is that they expect children to be able to read!
- Should you teach for mastery before moving on to a new concept? Or should you just move a child on and forget what is not known?
- Are we exposing children to too many concepts before they have grasped even one?
- What are alternatives to a curriculum for slow learners in junior high school mathematics?
- How can the state syllabus be changed?
- Does test anxiety affect test validity?

Regarding instructional methods–

- What types of hardware and software materials could one use for students with visual and auditory perceptual problems pertaining to concrete and abstract concepts?
- Needed: ideas for motivating slow learners at each level.
- Do children need more exposure to concrete approaches before they should be expected to think abstractly?
- What instructional aids and filmstrips are available for the different math areas?
- What are the techniques for teaching division?
- Needed: math activities and games for seventh and eighth grade students.
- Will games teach mathematics? What games?
- Needed: methods of introducing and applying the metric system.
- How might calculators be used in the classroom?

These questions provided focus for materials and activities used at each class session as well as for discussion. Background and current information provided by the instructor and by readings about such topics as the National Assessment of Educational Progress, the modern versus traditional controversy, back to basics movement, classroom use of hand-held calculators, computer usage, and innovative programs in operation, as well as student-provided resources, fit well into this format. The sharing of experience and expertise among class members led to interesting and unexpected areas. Of course, it also provided solid information for many of the topics. Illustrations of several thought-provoking sessions and activities which were created by class members are briefly described here.

- A survey was designed which required one to identify the grade level at which a particular skill was introduced. (The New York state syllabi were used as the key, since some variability would occur across text series.)

- Elementary art and music teachers demonstrated ways in which they incorporated mathematical ideas in their teaching.

- A member of a three-county curriculum committee (who happened to be enrolled) shared the product as well as the process and issues involved in producing it.

- As a result of seeing the Madison Project movie, *A Lesson with Second Graders*, a secondary teacher questioned whether second graders could do such work with signed numbers and coordinate geometry. Second grade teachers in the class also differed in their opinions. The secondary teacher borrowed a second grade class, worked with them, and reported back with positive results and amazed respect for young children's abilities.

- Small computers were demonstrated and ideas for activities shared.

- A second grade teacher (also enrolled), who is extensively involved with using and sharing teacher-made aids on the state and national levels, provided a wealth of inspiration and information during a show and tell session.

- A variety of readability measures was applied to texts.

This workshop format for combined groups of in-service elementary and secondary teachers was quite successful. The fact that it drew many teachers to enroll who had no need to accumulate graduate credit may be viewed as some indication of a need for such a course. In addition to achieving the goals of the course, specific needs of individual class members were met as well. The most rewarding outcomes were that elementary teachers appeared to gain confidence in their abilities regarding the teaching of mathematics and that secondary teachers seemed to develop a new-found respect for elementary school mathematics, elementary teachers, and the abilities of all students.

THE URBAN-BOUND MATHEMATICS TEACHER

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"In American Schools today. . .at the high school level, about 9 million students are enrolled in hundreds of different special courses ranging from remedial arithmetic and elementary algebra to computer science and calculus. These students are taught by at least 75,000 different teachers--most specialists in mathematics, but. . .with widely varying abilities, objectives, and methods for mathematics instruction." (16:iii)

Not only do the teachers have "widely varying abilities, objectives, and methods," so also do the students they are asked to teach. Too often the beginning teacher is ill-prepared for the situation found in the modern inner-city school. The problems present themselves in overwhelming fashion. Most are not simply problems of what to teach or how to get a ditto master run off. It is true that these can be problems; however, they were dealt with during the pre-service training program.

The following case study illustrates the problems our beginning teacher may face and must overcome.

I was a student in a small midwest high school who found it extremely easy to excel in the academic arena. My family life was reasonably comfortable, but there was no pressure to push me toward college. My high school advisor practically forced me to take the College Board Exams for the National Merit Scholar Program where I scored high enough to be a finalist and was offered scholarships at a number of prestigious colleges and universities across the country.

My choice was an elite, private college in the midwest where I received an excellent training in the arts tradition. My major was mathematics, and I found it easy to acquire minors in English, German, General Science, and Education. The mathematics major included the usual courses in College Algebra and Trigonometry, Analytic Geometry and Calculus. The upper division courses consisted of advanced Calculus, Probability and Statistics, Foundations of Mathematics, Abstract Algebra, Modern Geometry, and a course in Logic and the Scientific Method. The minor in education included Introduction to Education, Psychology, Psychology of the Adolescent, Methods of Teaching (Mathematics), and Student Teaching. The students in my student teaching classes at the local high school of a small midwestern town had reasonably homogeneous backgrounds and abilities.

Up to this point, everything was going well. My professors were pleased with my progress and the students in my classes were doing

well. I had no indication of the pain and anguish I would experience only a few short months hence.

I was interviewed by representatives of 15 to 20 schools who came to my college. (At this time there was a significant shortage of mathematics teachers.) I chose the most attractive of several direct contract offers—a junior high school in Berkeley, California.

Willard Junior High in the early 1960s offered a classic example of de facto integration. Its racial balance matched that of the city—45 percent Black, 45 percent White, 10 percent other. Indeed, Willard Junior High was used as a model for a number of federal court desegregation orders. The educational model implemented was homogeneous grouping at each of the seventh, eighth, and ninth grades. The use of I.Q. scores and previous grades allowed grouping into seven tracks in the seventh and eighth grades and five in the ninth grade. As might be expected, this caused a school which was perfectly integrated to the casual observer to be almost completely segregated. The three lowest tracks at the seventh and eighth grade levels were 95 percent Black, and the three highest tracks were 95 percent White. Only in the middle tracks did one find a modicum of integration.

As a first-year teacher, I was assigned to four bottom classes and one middle—the ones the experienced teachers didn't care to teach!! For me it was an extreme case of "culture shock." How do you respond when the manager of the local Five and Dime comes to the principal and accuses you of encouraging shoplifting? I suppose I did. After all, I told one seventh grade class they each had to bring their compass and protractor the next day. . .and they did. And how do you deal with the eighth grade girl who comes into class and cusses you up one side and down the other for giving her seventh grade brother an F on his test, for which he was slapped around at home by their stepfather? Or what about the seventh grade girl who is so tired she sleeps through your first period class at least three days a week? Upon questioning, she confides that her mother has left with another man and she has been supporting two sisters and a little brother by streetwalking. I was ready to quit several times in the first semester. The principal was understanding and allowed me to vent my anger, fears, and frustrations, and found ways to help me over each rough spot as it appeared.

Most of these were not academic problems. Rather, they had social, economic, or psychological roots. Many of them were foreign to me. I had no knowledge of them in my home town or college training. This caused my first year to be indeed "on the job training." It was not good for my students, and it most certainly was not good for me. There is enough to be learned in dealing with students on your own for the first time so that no time should be required for such learning experiences.

The problems suggested by the case study are not the only ones facing teachers today. The job market is exceedingly tight. In many areas school populations are down or are decreasing. This leads to declining fiscal support and school retrenching. Increased restrictions are imposed by state and local governments. Many changes in form for teachers as well as for students and administrators will be occasioned by the implementation of competency-based teacher education (CBTE), the use of calculators and computers, and an increased emphasis on problem-solving and applications in the mathematics classroom.

In a 1974 study undertaken for HEW, Carroll and Ryder at the Rand Corporation predicted an oversupply of teachers through 1980. They developed a new model which suggests that other forecasts of overproduction may be rather significantly too pessimistic. While Carroll and Ryder predict an oversupply through 1980, they observe that it will be paralleled by declining numbers of new teachers in the 1970s. Thus, when the oversupply ends they believe "the inertia in the system will lead to the almost immediate on-set of a substantial and lengthy teacher shortage." (7:103)

The legislature of Colorado has passed a law that all state expenditures will be cut by 5 percent for fiscal 1977; after that they will be increased only at the rate the population increases. This applies to state support for education as well as other state enterprises. The Colorado State Department of Education has instituted a requirement that all secondary teachers must have a course in the teaching of reading in the content areas. This is designed to provide for the student who would otherwise slip through the cracks of the system and emerge with functional illiteracy.

Another area where there is outside pressure for change is in competency-based teacher education (CBTE). This pressure is coming from state departments of education. In 1974, a survey of state-level activities on CBTE was conducted by the Multi-State Consortium on Performance-Based Teacher Education (PBTE). This survey found that in the 50 states and the District of Columbia: 5 have some form of competency-based certification in use; 23 report some definite official action already taken to move toward CBTE or competency certification; 23 report they are in some stage of investigating or studying the concept (18).

There is a good bit of controversy circulating about the concepts of CBTE and PBTE. They are being implemented to satisfy the need for accountability being expressed in education. Critics say they do not account for many skills, interactions, and concepts which are not easily quantified. There is also a very limited research base to support the ideas. Heath and Nielson believe that "an analysis of the research on the relation between specific teacher skills and student achievement fails to reveal an empirical basis for performance-based teacher education." (9) They further state that the PBTE model "ignores *what* is to be taught. . .[and] the model ignores *who* is to be taught." These are strong statements; nevertheless states are moving ahead with their implementation of CBTE or PBTE.

Today's teacher must deal with problems and opportunities which were rarely considered or never thought of as recently as a decade ago. The computer and electronic calculator have come of age. Metrication is a vital issue which must become second nature. The ideas of problem-solving and mathematical modeling have often been given lip service, but are now forcing themselves on the teaching community.

The rapid growth in the field of computer technology leads to the question, "How can we best use it in the public school?" Several options are available. The first is as a data management tool. In this role it is possible to offer individualized instruction by having the computer keep track of what the student has learned and what he/she has yet to learn. The computer can also test, score, and generally alleviate an enormous clerical problem for the teacher. Baker has reviewed a number of such applications and believes that their "promise far exceeds the present accomplishment." (3)

Another option for computer use is as an indefatigable tutor. Computer assisted instruction (CAI) is another way to offer individualized instruction. Gibb notes that "the immediate feedback and the undivided attention that the machine can give. . .may be the critical need of an individual student at any given time." (8) While most teachers would be happy to have the management aspect available, some would feel threatened by the tutorial aspect. The tutorial mode can appear to take from the teacher a primary function. However, the computer is "dumb"; while it has a prodigious memory, it requires a dedicated teacher to provide "much time, creative thought, and energy. . .to instruct [it] so it, in turn, can instruct its students." (8)

A third computer use is as a very fast computational device for students. Kieren, McGuire, and Allison each indicate ways the computer can be used in the classroom (11, 13, 1). All require a programming language: either BASIC or FORTRAN. Atchison notes that "Marvin Minsky in his 1970 ACM Turing Lecture remarked that eventually programming itself will become more important even than mathematics in early education." Thus students can use the computer as a tool to develop "their ability to think, plan, create, and organize for themselves." (2)

The teacher is an important part of each of these applications. Kieren offers a model for implementation of the computer in aiding instruction. He observes that "effectiveness is highly dependent on human planning. . . ." (11) This planning can only be carried out by a person familiar with the computer–its capabilities *and* its limitations. Such familiarity comes from working with a computer; it can be acquired in formal coursework taken by the pre-service teacher.

The electronic calculator has made instant, low-cost, arithmetic accuracy available to everyone. There is still much disagreement as to its place in the classroom. Several pros and cons are discussed by Machlowitz, but it seems clear that the electronic calculator is here to stay (14). Many materials are being written for classroom use and some research has been carried out to validate procedures.

Although research is inconclusive at this time, it seems to say that the use of the electronic calculator doesn't hinder the learning of mathematics (5, 6).

The implementation of the metric system or "metrication" has elicited a considerable amount of discussion. The November 1974 issue of *The Mathematics Teacher* has several articles dealing with this area of concern. Since mathematics teachers at all levels will carry the main load in furthering metrication, they will find especially useful a metric bibliography prepared by Stuart C. Choate as part of the work of the Metric Implementation Committee of the National Council of Teachers of Mathematics (NCTM). Even now textbooks are available at the elementary level which deal exclusively with SI (Systéme International d'Unités) units of measure (20).

Problem-solving and mathematical modeling may be the most important aspects of today's mathematics education. Troutman and Lichtenburg (19) decry the practice of giving "handout sheets of problem after problem where the 'problem' is a computation to be carried out and the 'answer' is recorded above, below, or on the line." They would have teachers provide realistic "situations that have to be interpreted and that need some structure imposed on them. More often than not, that structure involves a mathematical model." Part of problem-solving is "problem-posing." Various problem-posing strategies are proposed by Brown and are illustrated in the context of the golden rectangle of ancient Greece (4). This is very similar to the emphasis given by G. Polya in his little book, *How to Solve It* (17). Unfortunately, a teacher very often has not had these approaches modeled in any undergraduate mathematics class and will find it difficult to implement them without specific training.

"Published recent data on the requirements in mathematics and mathematics teaching methodology of pre-service teacher education programs are non-existent." (16:81) While this was generally true in the area of secondary mathematics education up until 1975, a study by McCowan in 1975 and another by Johnson and Byars in 1977 have helped to fill the gap (12, 10). Both studies determined to what extent colleges and universities met the Level III recommendations of the Committee on the Undergraduate Program in Mathematics (CUPM). These recommendations include the following requirements: three (semester) courses in calculus, one course in real analysis, two courses in algebra, one course in probability and statistics, one course in geometry, one course in computing. Both studies discovered that not all schools met all recommendations. In fact, McCowan found that no schools in his survey required all recommended courses. He feels that teacher preparation falls "far short of recommendations. . .of CUPM." It is encouraging to note, however, that Johnson and Byars found that 69 percent of their respondents "endorsed the CUPM recommendations." Indeed many of these respondents indicated they were working toward closer conformity with these recommendations.

The pre-service program for secondary mathematics teachers at Metropolitan State College (MSC) was designed to alleviate many of the problems outlined (15). MSC has defined three components for the program of teacher education. The

first part of the curriculum, general education, includes courses in communications, humanities, and natural and behavioral sciences. It is designed to allow teachers "to serve as models of educated persons."

The second part is the teaching major. The Secondary Education Program in mathematics is offered through the Department of Mathematical Sciences. CUPM Level III recommendations were followed in great measure to determine requirements for the major. Thus, the following courses are required:

1. Two semesters of calculus with analytic geometry
2. One semester of proofs and abstract mathematics
3. One semester of computer science
4. One semester of abstract algebra
5. One semester of probability and statistics
6. One semester of history of mathematics
7. One semester of foundations of geometry
8. One semester of methods of teaching mathematics

In addition, the prospective teacher must take two more courses. These are usually chosen from calculus, number theory, linear algebra, statistics, and computer science.

The major as presented is designed to reach several goals. First, it gives the prospective teacher a solid base for teaching most of the courses in the secondary school. The proofs and abstract mathematics course is required of all mathematics majors and gives the teacher candidate an opportunity to "do real mathematics." Only the history, geometry, and methods courses were designed specifically for the Secondary Education Program. About one-third of the students in the history and geometry classes are majoring in other areas of mathematics and take these courses as electives.

A second goal is to prepare the teacher to the extent that graduate work in mathematics is a real possibility. In fact, several of our teacher candidates have decided to obtain a master's degree before teaching. Colorado also requires ongoing education for recertification purposes. Graduate-level mathematics courses are accessible to our graduates.

A few of our teacher education majors decide, either before or after graduation, that they will not teach. The program as presented allows them to pursue other career goals with relatively little additional coursework. Other students find that teaching is not "their cup of tea" after being in the field for some time. They also have a good base to work from in a retraining effort.

The methods course is designed to make the student aware of professional aspects of the teaching of secondary mathematics. Topics from the history of teaching mathematics are covered with emphasis on the period from 1900 to the present. Learning theories as they apply to teaching mathematics are discussed. This allows each student to develop and formalize a personal theory of teaching.

Ordering and pacing of material and evaluation are considered in the light of this theory. Various audiovisual capabilities are developed. Students are asked to create an overhead projector set for a daily lesson. They prepare a tape cassette unit for self-help. They give three class presentations of 10-15 minute length. This forces them to organize their material much better than a regular class-length presentation might. One of these presentations is videotaped to give students the chance to pick up problems in speaking before a group of which they might not otherwise become aware. Each creates an annotated bibliography for a secondary mathematics library. In addition, each tutors at the algebra level two hours per week for the semester. All this is done with a view toward having a very successful student-teaching experience and, more importantly, an equally successful teaching experience.

The final component of the MSC program is the sequence of professional education courses. This consists of clinical and laboratory field experiences as well as classroom lectures and seminars which are given in three different semester blocks. The first block is theory and practice of social and cultural bases of secondary schools. Here the clinical aspect in the public schools allows teacher candidates to deal with problems and needs of adolescents from diverse ethnic and cultural backgrounds. The next block deals with the theory of the psychological and physiological bases of secondary education. This allows the teacher to develop a theory of learning and strategies for the "exceptional" child in the classroom. The final block is a group of three courses in the processes of education. This segment includes general materials and techniques, and the use of media in the classroom. It also includes a laboratory experience in the community schools where the student is asked to tutor in an individual and small group situation.

After all coursework is completed, the student-teaching experience is taken in an accredited public or private secondary school. Here increasing responsibility is taken for teaching, supervision, and direction of an identified group of learners. This is the final supervised experience before the teaching credential is awarded.

In addition to required courses and formal work toward the bachelor's degree, all teacher candidates must complete at least 200 clock hours of volunteer work. Candidates work with adolescents in the age bracket they intend to teach. Volunteer work may be accomplished with groups such as Boy Scouts, Girl Scouts, church groups, volunteer tutor programs and similar activities. It is to be completed by the end of the sophomore year.

The MSC program is designed to expose the prospective teacher to the gamut of possible experiences in a nonthreatening atmosphere. It treats both theory and practice in situations of gradually increasing responsibility. It appears to be a successful program. Our graduates have been enthusiastically received and have found positions when graduates of other institutions have been told none exist.

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In *Mathematics Teacher Education: Critical Issues and Trends* the Editor, Douglas B. Aichele, comments: "Mathematics teaching today faces the future with little real certainty of its goals and little optimism concerning its potential effectiveness; this bleak outlook has resulted largely from the lack of hard research data as a basis for making decisions." He stresses the significance of the 1975 NACOME report which "... capitalized upon several current nationwide research projects and clearly has significant and far-reaching implications for mathematics teacher education at all levels. It provides the central theme or core for *Mathematics Teacher Education: Critical Issues and Trends.*"

This publication in the NEA Professional Studies Series begins with a research-supported discussion of several timely topics facing mathematics educators, and is followed by five specific aspects of mathematics teacher education. Kathryn Castle considers the areas of kindergarten mathematics; John Mihalko discusses math anxiety, individualization, and learning theory as they relate to mathematics teacher education; Frank Rogers reviews the training of teachers for junior and senior high schools; Karen Skuldt describes a graduate in-service K-12 workshop course; and Earl Hasz focuses on some of the challenges facing secondary mathematics teacher education in an urban environment.

Mathematics Teaching Education: Critical Issues and Trends presents a variety of overviews, position papers, and program descriptions which can provide a more objective base for making decisions in mathematics teacher education. The consultants on this project have indicated the book will be helpful for individual teachers, as a resource for an in-service project on the local level, and as reference and resource material for mathematics department libraries.

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